Systems Engineering Implementation in the development of the Airborne Icing Tanker at the Air Force Flight Test Center

A Department of Defense Central Test & Evaluation Investment Program (CTEIP)

By
Saul Ortigoza
Project Director
Airborne Icing Tanker
412th TW/DRP

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AGENDA

- Background
- Test History
- System Description
- System Requirements
- Systems Engineering Evolution
- Rebirth of a National Asset
- Conclusion

Background

- Simulate natural icing conditions
- Simulate rain For water ingestion/erosion tests
- Safe flight test In high risk areas
- Repeatable, controlled test environment

Test History

GOVERNMENT			COMMERCIAL
B-58	F-15	F-14	Boeing 737
AV-8	F-4	AGM-109	Boeing 757
F-111	A-10	EA-6B	Canadair Challenger C1-601
A-7D	E-3A	AGM-129	Piaggio Avanti P180
SRAM	T-39	C-27A	Concorde
T-38	F-16	B-2	Mitsubishi MU-2B-60
C-130	F-18	C-17	CFMI CFM56
B-1B	KC-135R	V-22	General Electric CF-6
HU-25A	C-5	F-117	ATR-72
AGM-86	B-52		


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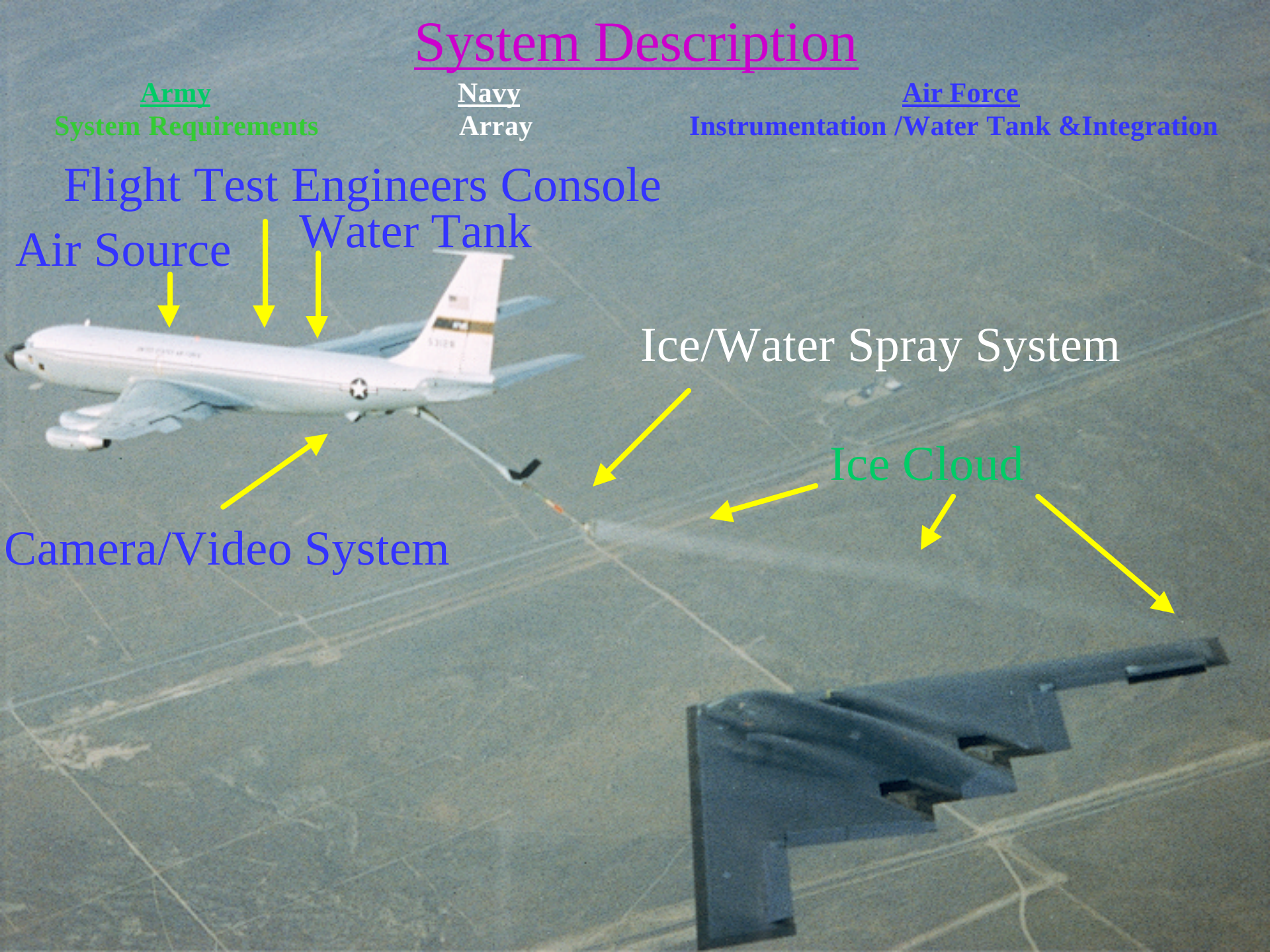
System Description

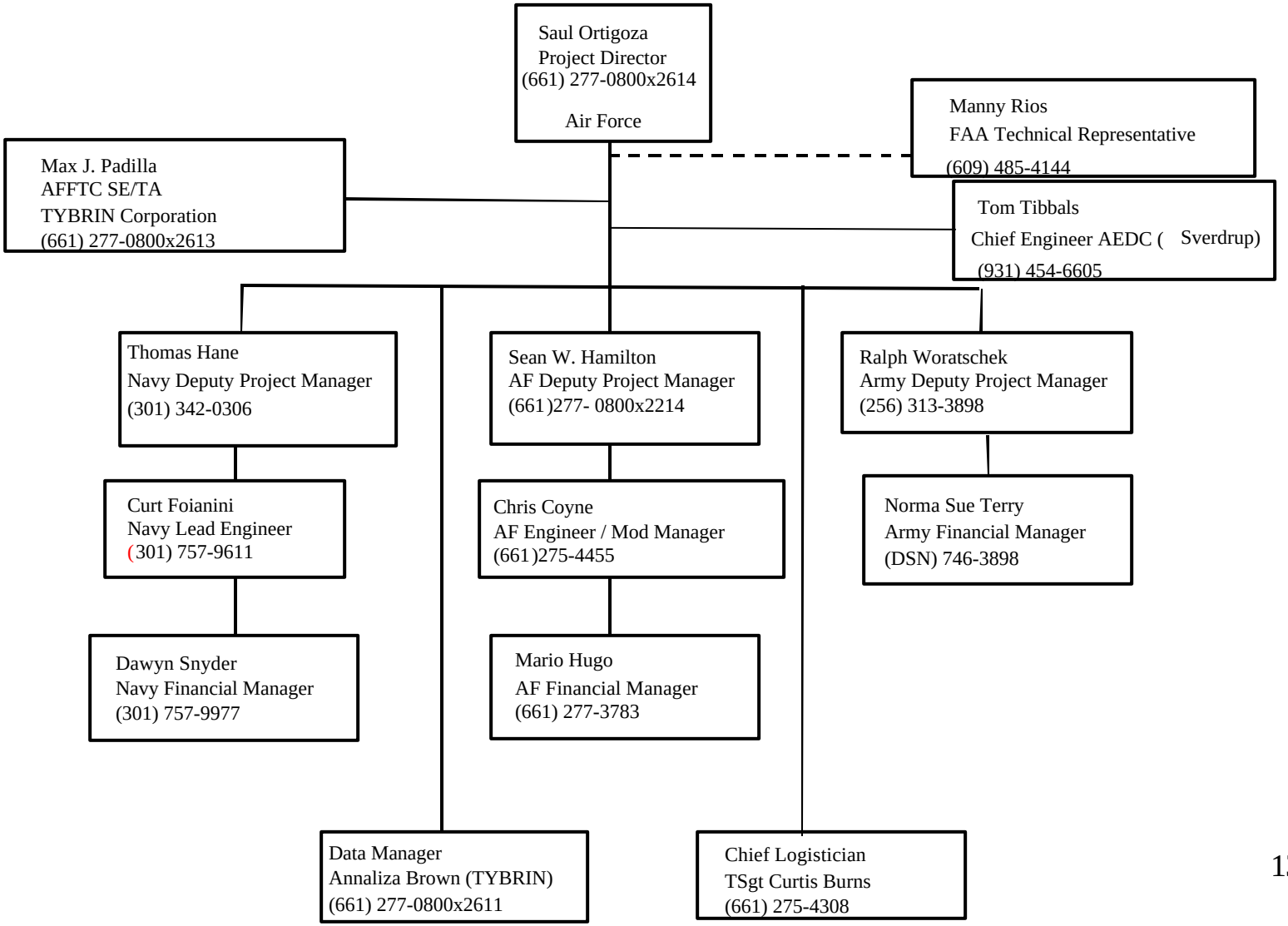
Army
System Requirements

Navy
Array

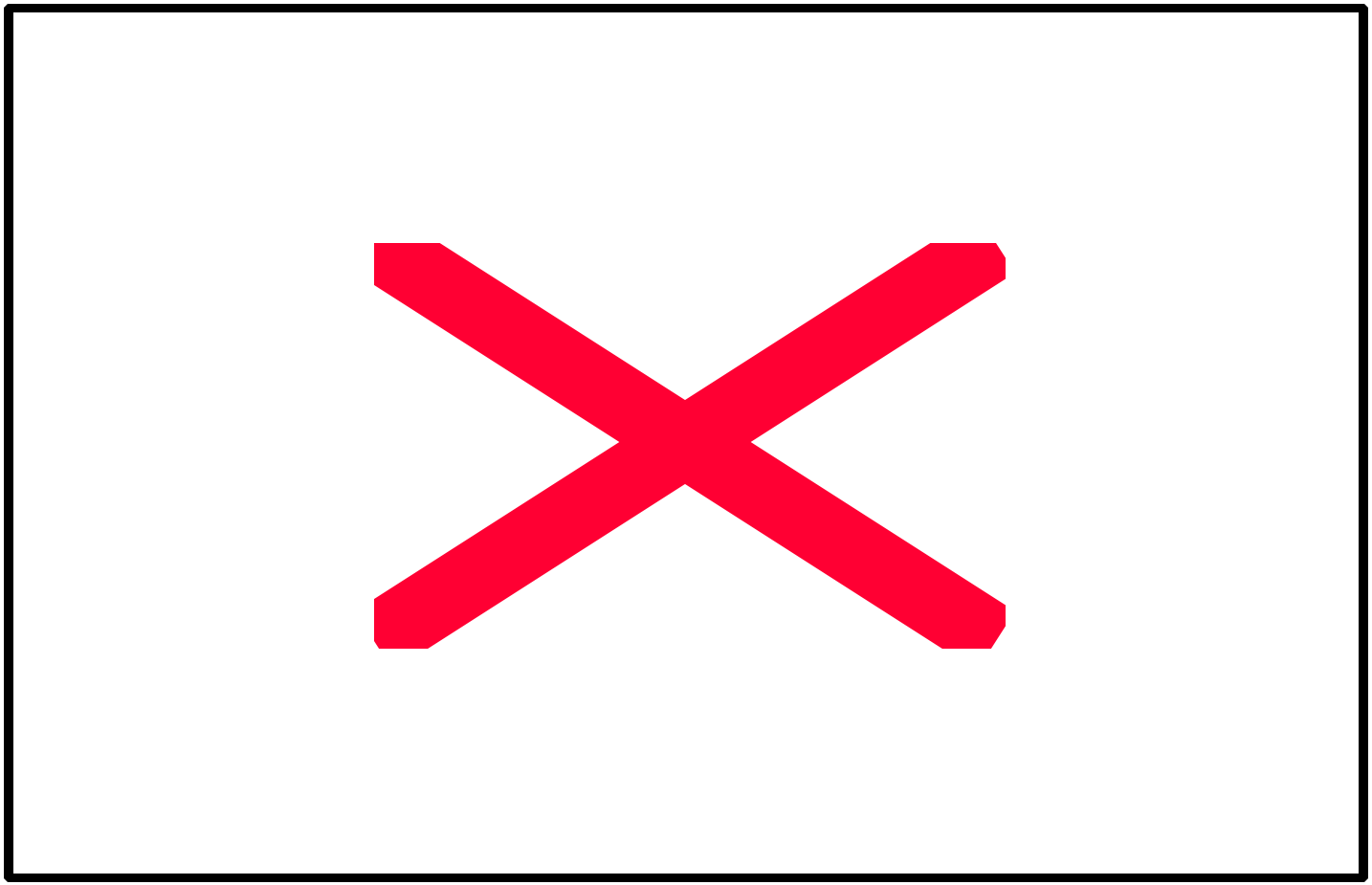
Air Force
Instrumentation /Water Tank &Integration



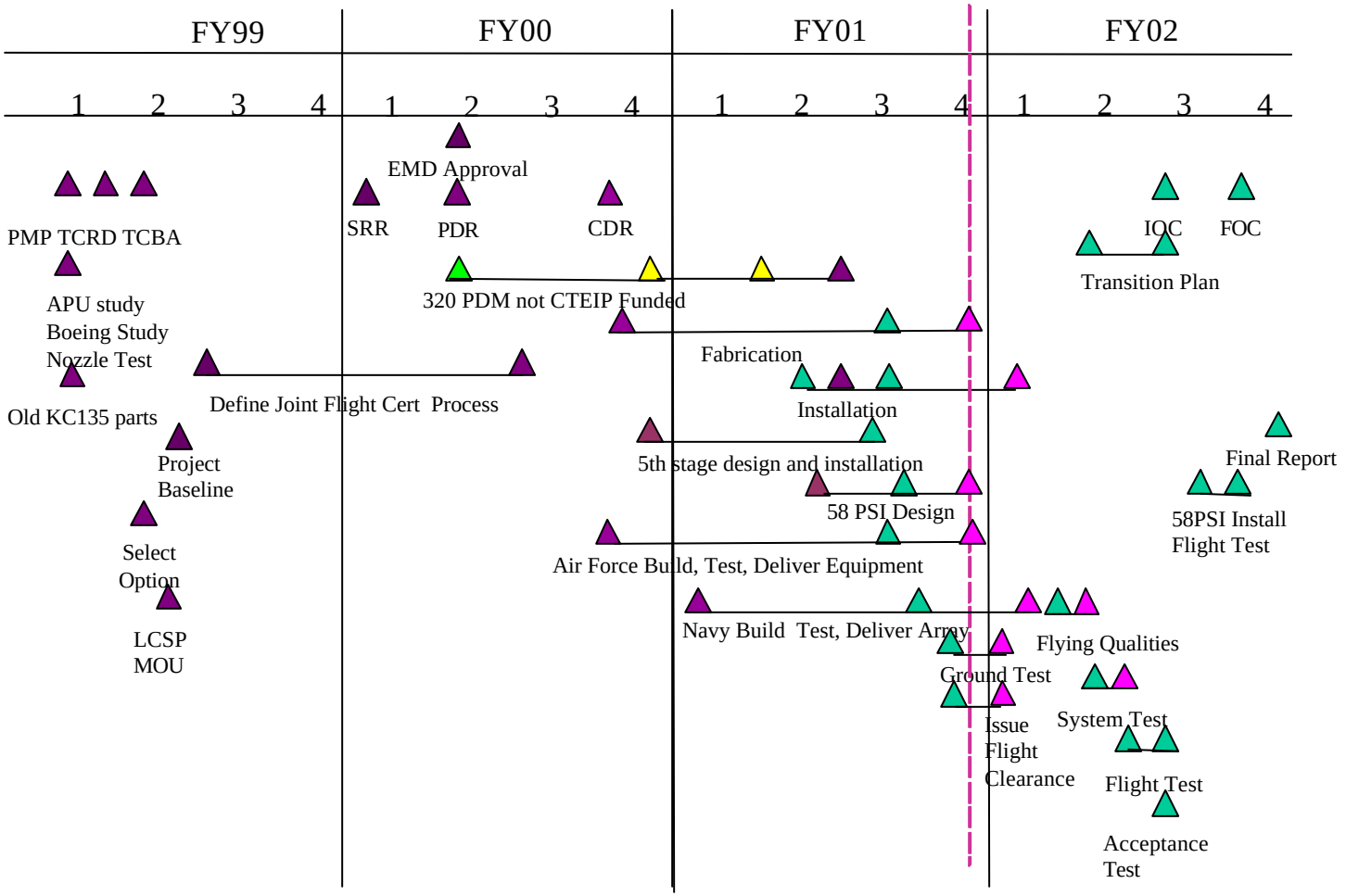
Organization



OBJECTIVE:
Ice the F-22 in 3Q FY02



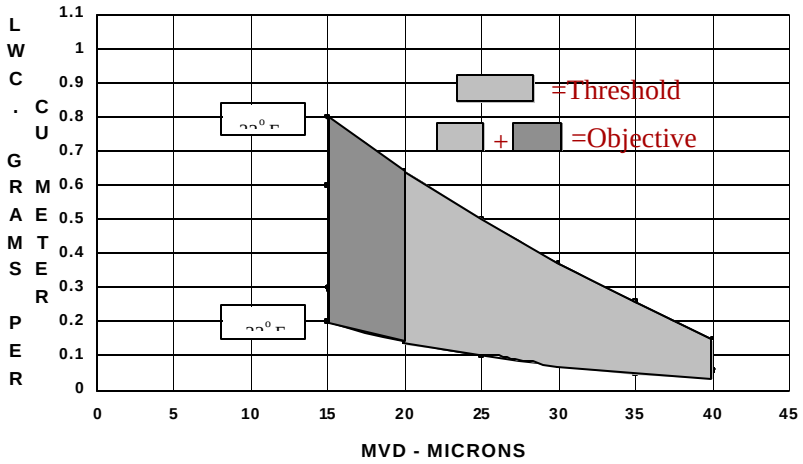
AIT Long Term Schedule



FAR Part 25, Appendix C Continuous and Intermittent Maximum Conditions

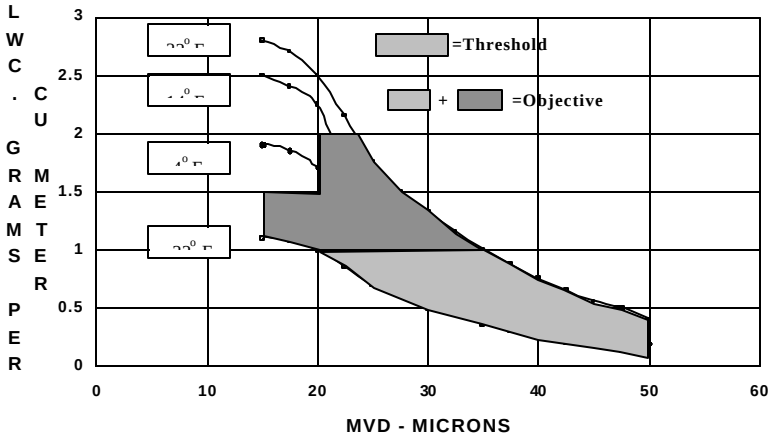
FAR PART 25
CONTINUOUS MAXIMUM (STRATIFORM CLOUDS)

LWC VS MVD

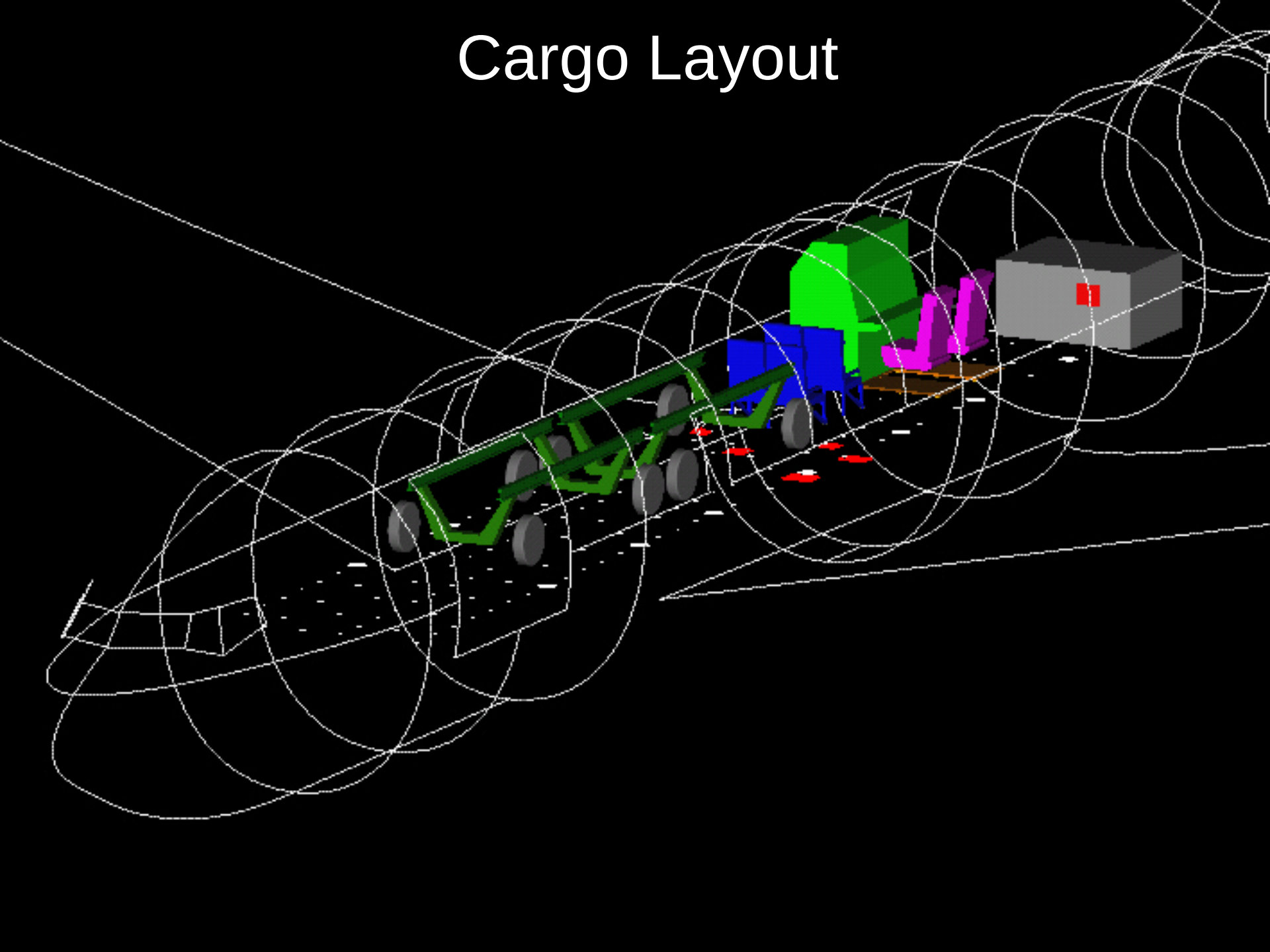


FAR PART 25
INTERMITTENT MAXIMUM (CUMULIFORM CLOUDS)

LWC vs MVD



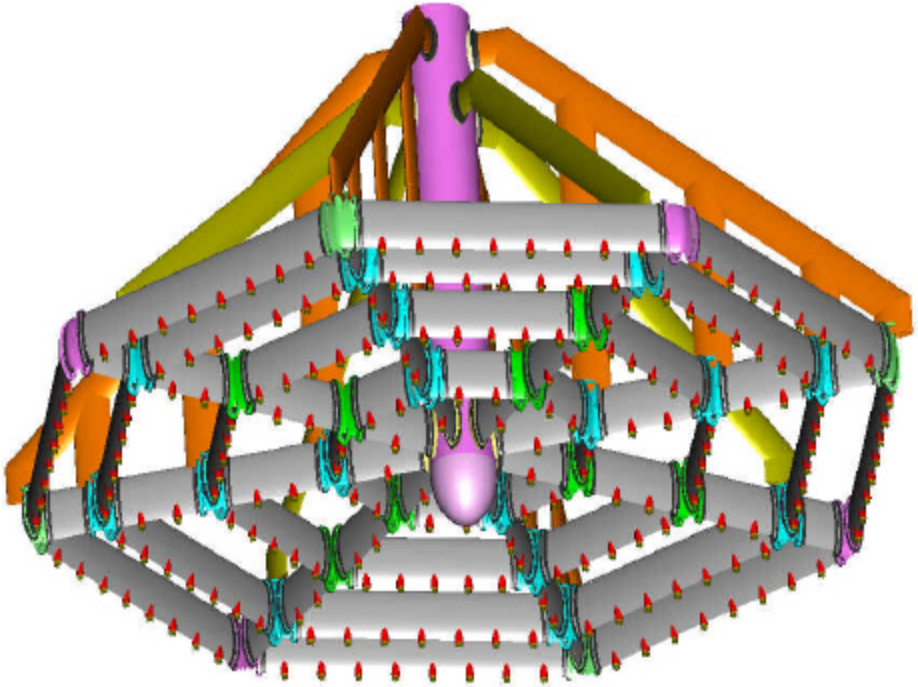
Cargo Layout



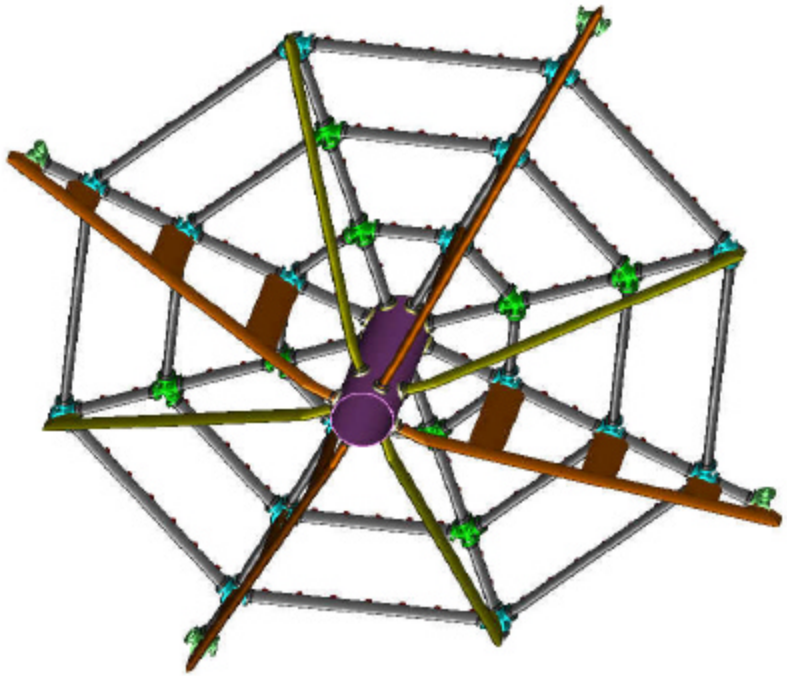

VCR

New Flight Test Engineer's Console

Spray Array Evolution

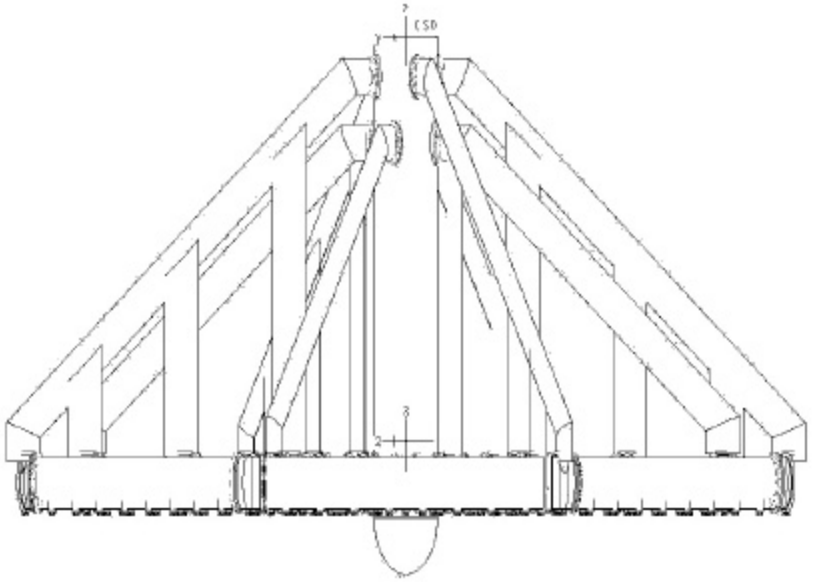


Initial Spray Array design

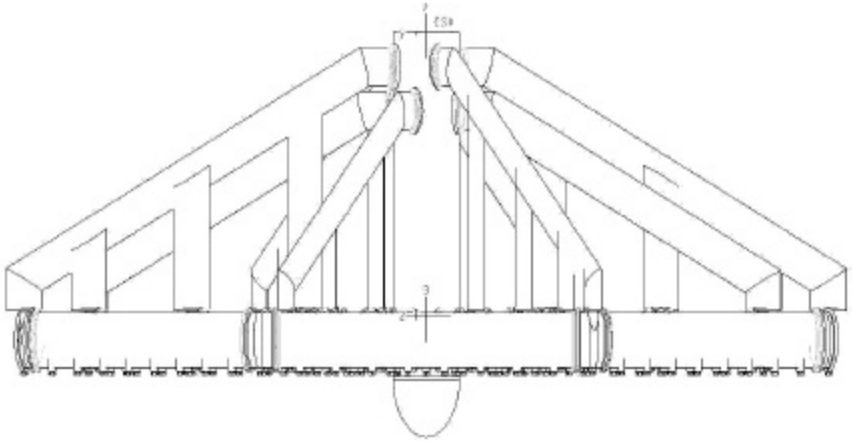


Hi Speed Configuration

Spray Array Evolution



Weight = 200lb.
C.G. = 35.35” aft.
Diameter = 6’
Height = 41.8” (excluding tailcone)

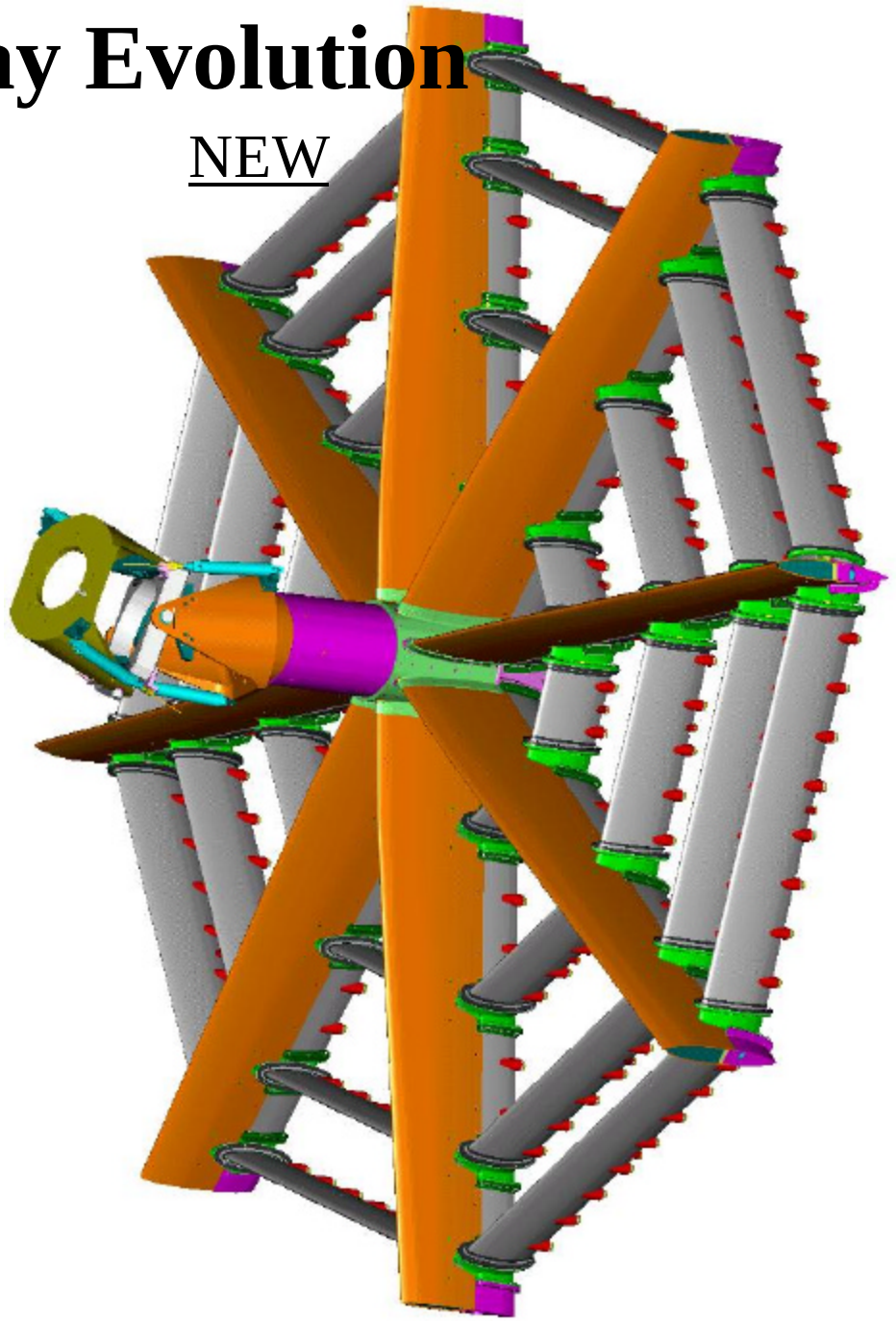


Weight = 190lb.
C.G. = 24.17” aft.
Diameter = 6’
Height = 28.6” (excluding tailcone)

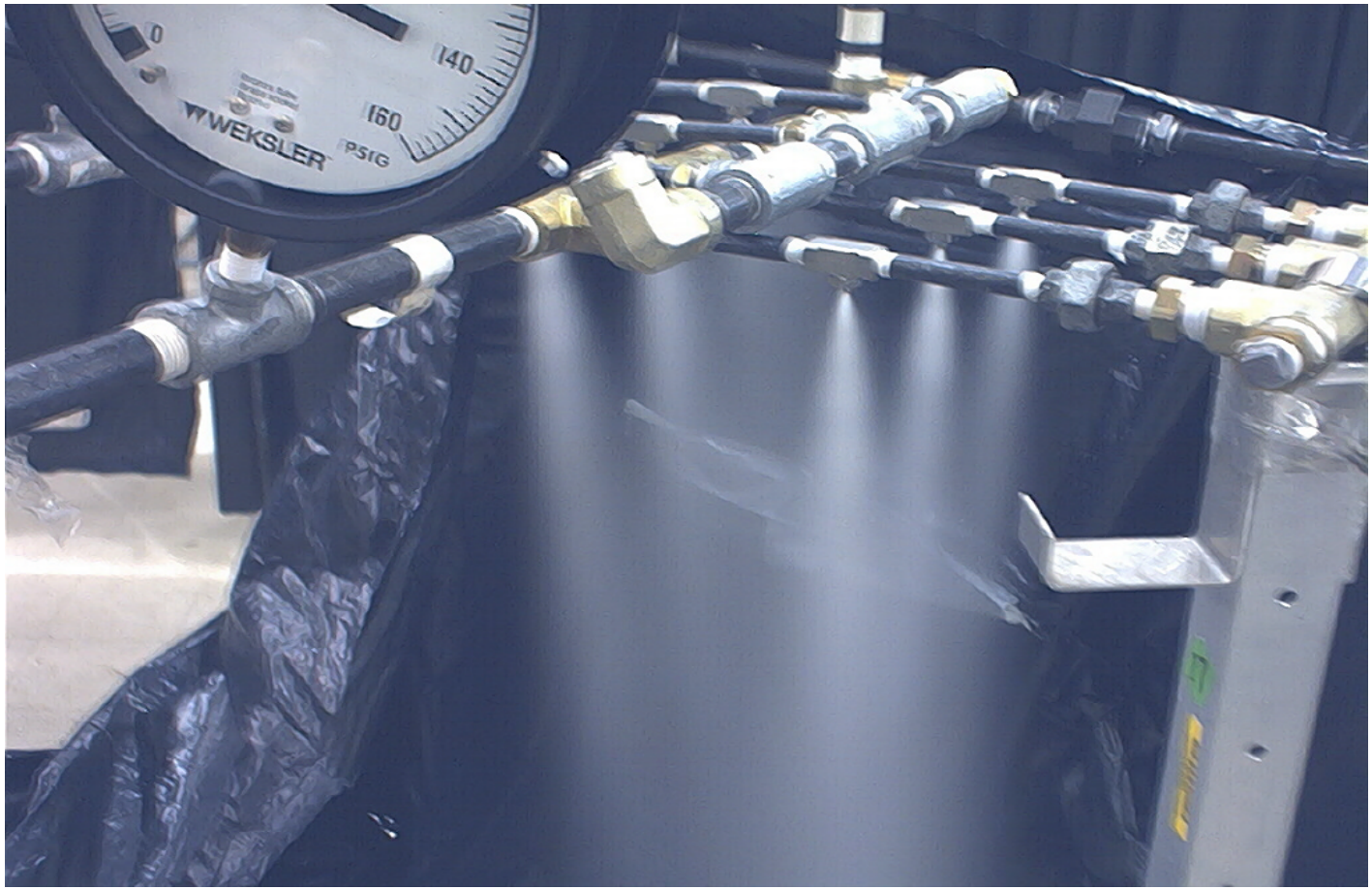
Spray Array Evolution

OLD

NEW

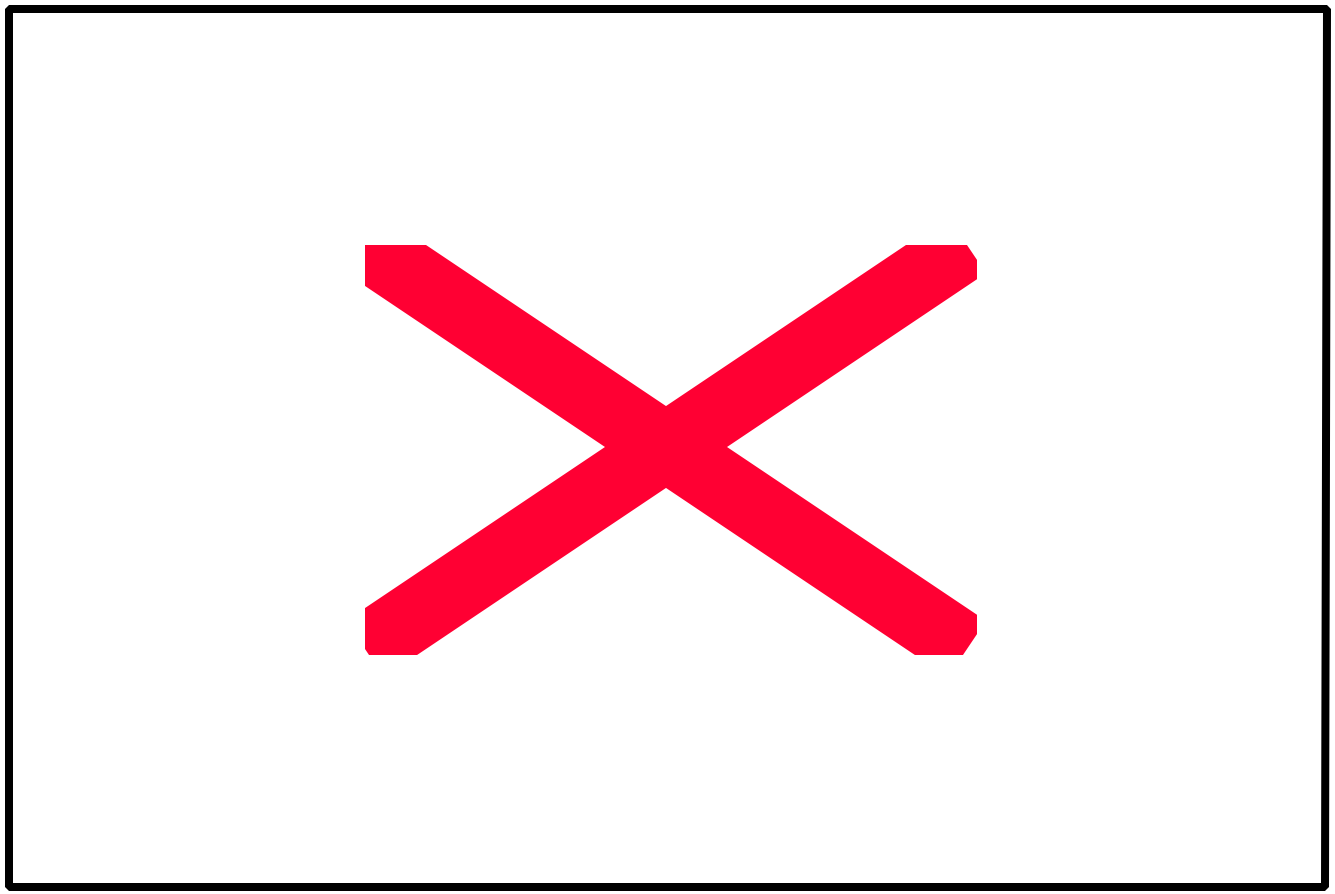


EXISTING AF NOZZLE

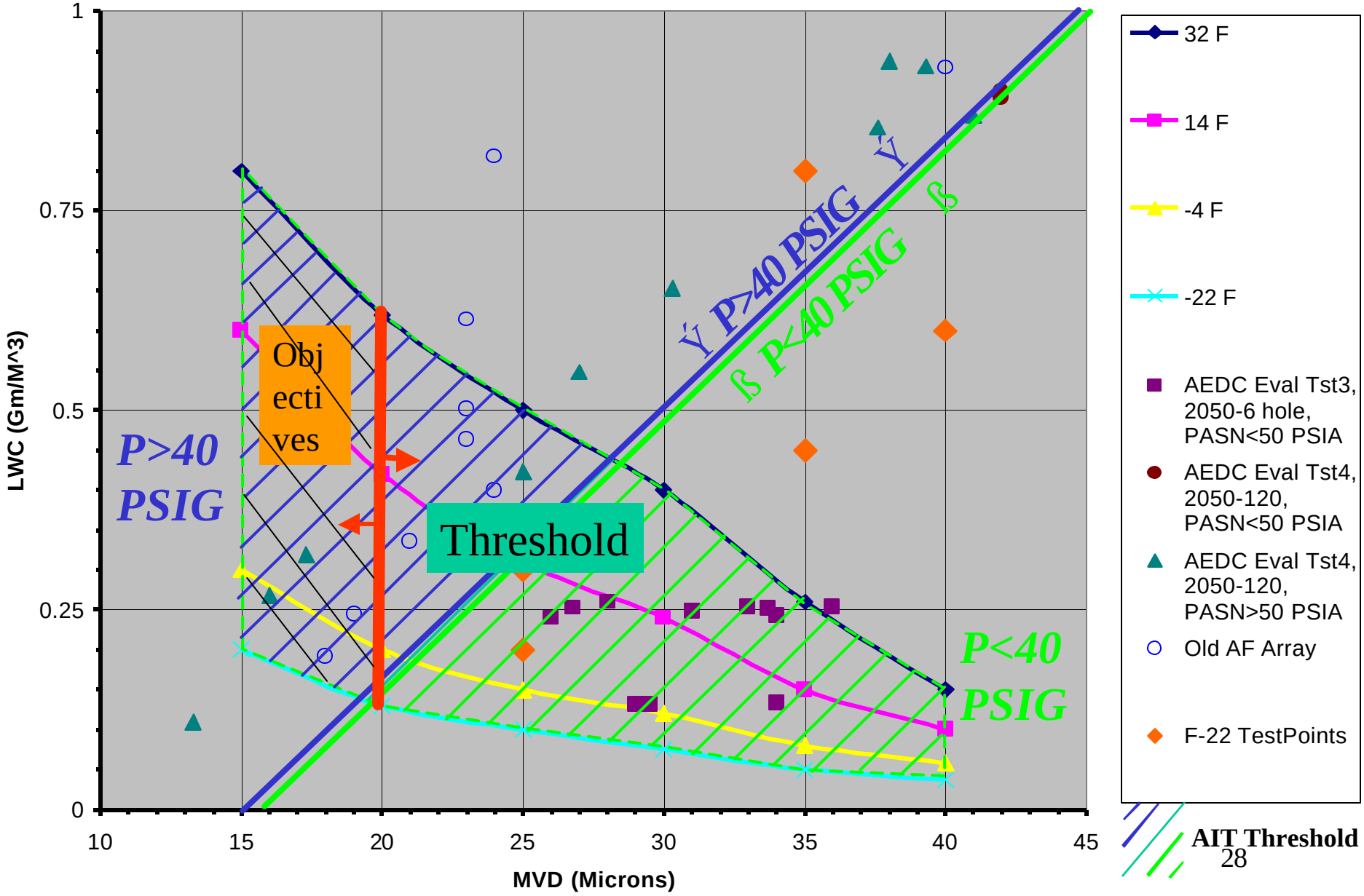


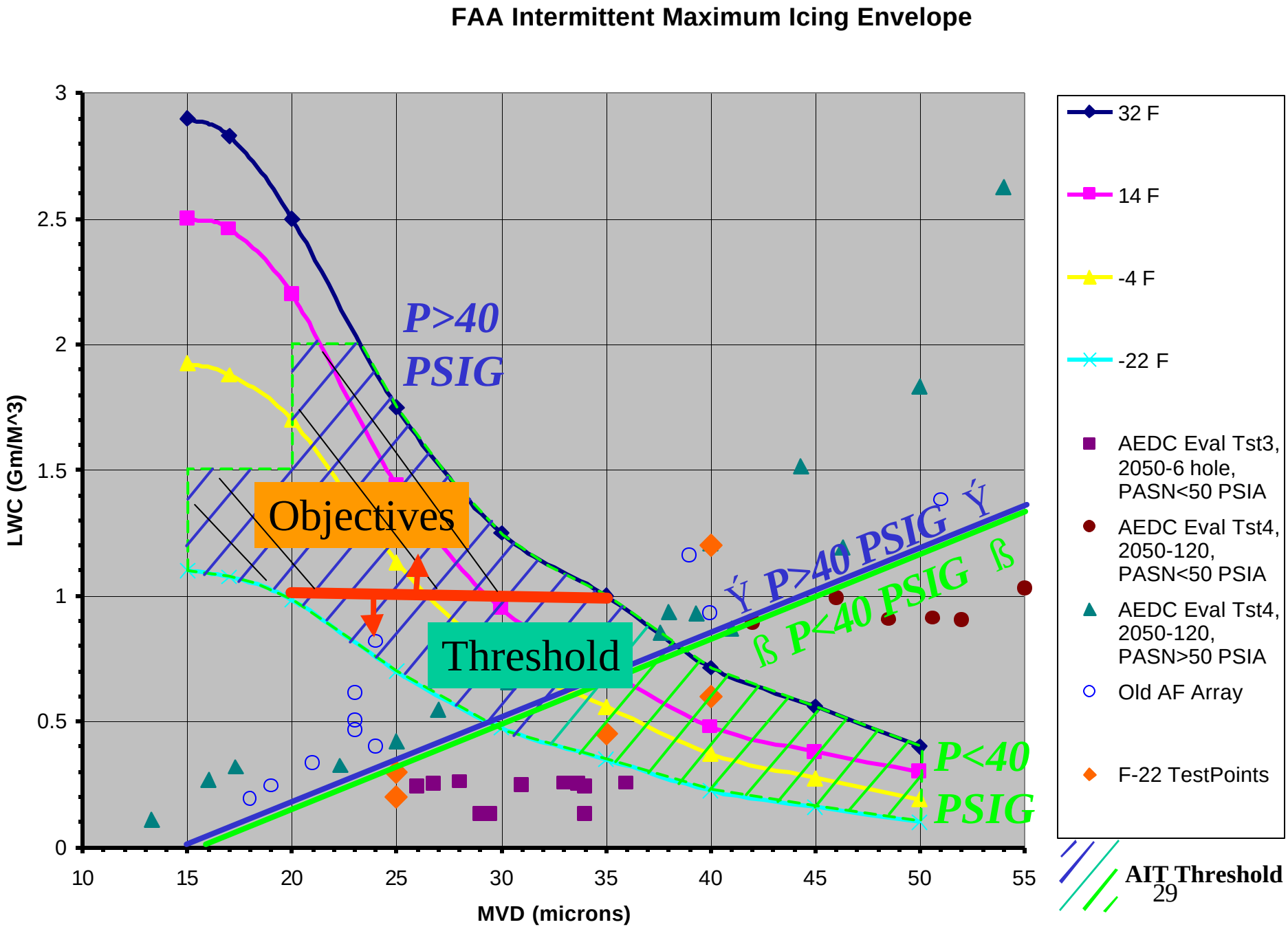
ONE CANDIDATE, 6100-37-70

AEDC Airfoil Tests



AIT Array Section with Spraying Systems2050-140-37-6-70 Nozzles


FAA Continuous Maximum Icing Envelope
LWC (Gm/M^3)
MVD (Microns)
1
0.75
0.5
0.25
0
10
15
20
25
30
35
40
45
P>40 PSIG
P<40 PSIG
Objectives
Threshold
32 F
14 F
-4 F
-22 F
AEDC Eval Tst3, 2050-6 hole, PASN<50 PSIA
AEDC Eval Tst4, 2050-120, PASN<50 PSIA
AEDC Eval Tst4, 2050-120, PASN>50 PSIA
Old AF Array
F-22 TestPoints
AIT Threshold


FAA Intermittent Maximum Icing Envelope
LWC (Gm/M^3)
MVD (microns)
0
0.5
1
1.5
2
2.5
3
10
15
20
25
30
35
40
45
50
55
P>40
PSIG
Objectives
Threshold
Ý P>40 PSIG Ý
ß P<40 PSIG ß
P<40
PSIG
32 F
14 F
-4 F
-22 F
AEDC Eval Tst3, 2050-6 hole, PASN<50 PSIA
AEDC Eval Tst4, 2050-120, PASN<50 PSIA
AEDC Eval Tst4, 2050-120, PASN>50 PSIA
Old AF Array
F-22 TestPoints
AIT Threshold

Enlightening Comments

- **"Just give me the requirements!"**
- **"We didn't bid on all this paperwork!”**
- **"Systems Engineering is only for mass production not just one or two.”**
- **"The ICD is complete”**
- **“What the User wants is gospel.”**
- **“The design is done. What? Another change?!!!”**

Heuristics

- **System Architecture**
  - **In Partitioning, choose the elements so that they are as independent as possible, that is, element with low external complexity and high internal complexity.**
- **Division of Responsibilities**
  - **Organize personnel tasks to minimize the time individuals spend interfacing.**
  - **Unless everyone who needs to know does know, somebody, somewhere will foul up**
  - **Being good at one thing doesn't automatically mean being good at something else**
- **Requirements Definition**
  - **Extreme requirements should remain under challenge throughout system design, implementation, and operation.**
- **Systems Engineering**
  - **To be tested, a system must be designed to be tested.**
  - **The greatest leverage in systems architecting is at the interfaces**
  - **Greatest dangers are also at the interfaces.**
  - **Be sure to ask the question, "What is the worst thing that other elements could do to you across the interface?"**

Heuristics Cont'd

- **Systems Engineering Continued**
  - **Testing, without understanding the multiple failure mechanisms to which a system is susceptible, can be both deceptive and harmful**
  - **Awash of paper, a small number of documents become critical pivots around which every project's management revolves.**
- **Design Concurrence**
  - **Once the architecture begins to take shape, the sooner contextual constraints and sanity checks are made on assumptions and requirements, the better**
  - **You cannot avoid re-design. It's a natural part of design.**
  - **Concept formulation is complete when the builder thinks the system can be built to the client's satisfaction.**
- **Verification & Validation**
  - **The test setup for a system is itself a system**
  - **The cost to find and fix a failed part increases by an order of magnitude as that part is successively incorporated into higher levels on the system**
  - **Simplify, Simplify, Simplify**
  - **If anything can go wrong, it will**
  - **Tally the defects, analyze them, trace them to the source, make corrections, keep a record of what happens afterwards, and keep repeating it.**

Successes

- **Improved Communication**
  - **Use of Specification and Interface Control Document increased communication between design teams**
- **Applying Systems Engineering to an iterative resolution of interface requirements resolves work stoppage and provides a framework for moving forward the design.**
  - **Helped to resolve tight real-estate in back of airplane**
- **Requirements iteration led to innovative design solutions.**
  - **Observers console turned to airline movie media approach and gained more cargo space for deployment.**

Failures

- **Time and money have been lost in two studies.**
  - **Looked at getting the air from different locations on the engine**
    - **This had a potential of saving a million dollars**
      - **Had this worked, you would probably be reading this under the successes heading.**
  - **Looked at improving the system to go above the objective.**
    - **The result was that it was possible to achieve**
    - **But the schedule and cost constraints would not be met**

Rebirth of a National Asset

Conclusion

The Airborne Icing Tanker is paramount to the safe flight of military and commercial aircraft throughout the world..